Degraded System Detection Requirements for Structural Monitoring Systems

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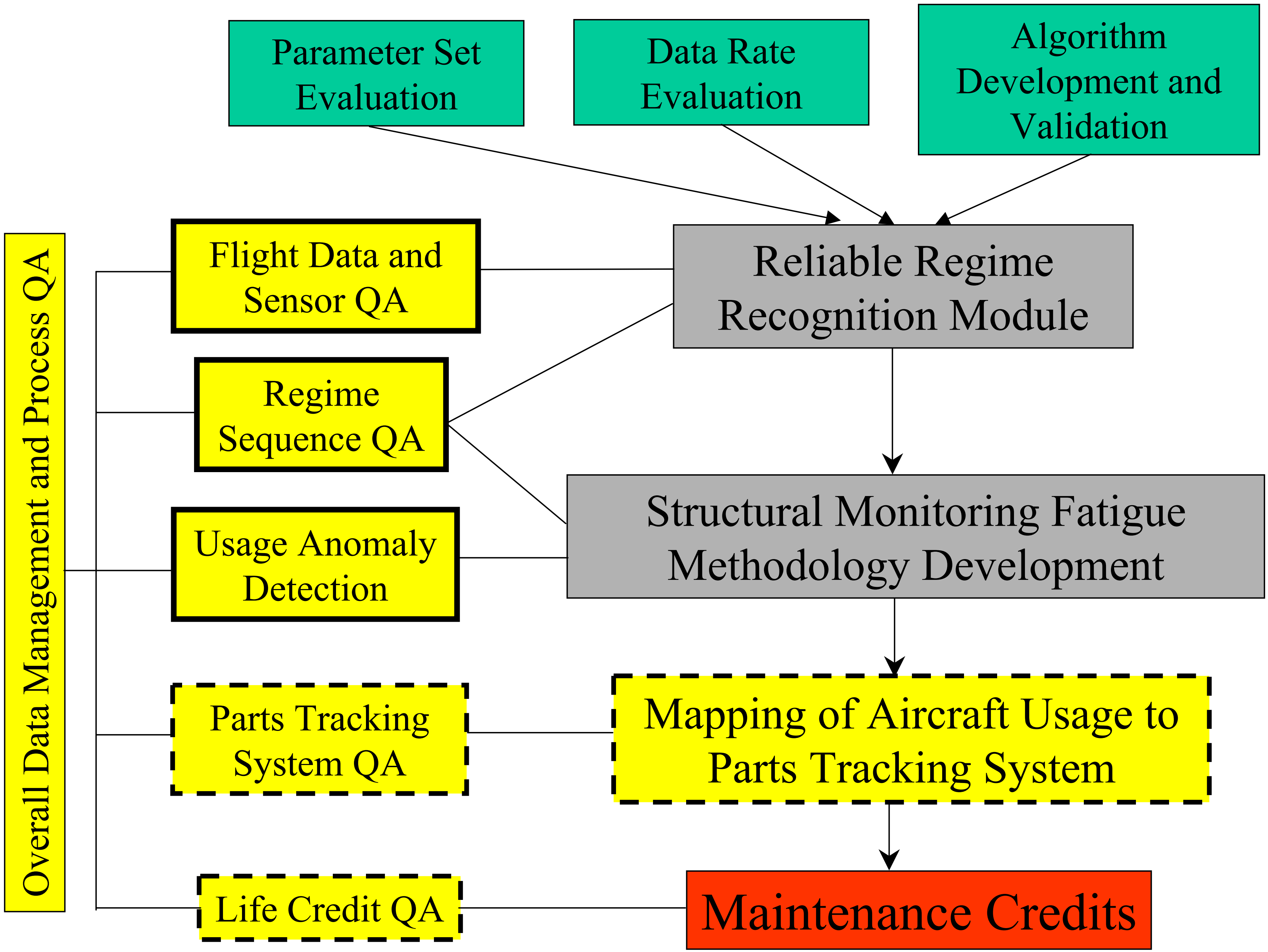
OBJECTIVE

- Provide assessment of Q/A (quality assurance) issues for various types of monitoring systems
  - Assess ease of detecting various levels of degraded system operation
  - Evaluate impact of system degradation on fatigue damage assessment
- Provide FAA with key information necessary to:
  - Define minimum acceptable system capabilities
  - Evaluate vendor proposed systems


Parameter Set Evaluation
Data Rate Evaluation
Algorithm Development and Validation
Overall Data Management and Process QA
Flight Data and Sensor QA
Reliable Regime Recognition Module
Regime Sequence QA
Structural Monitoring Fatigue Methodology Development
Usage Anomaly Detection
Parts Tracking System QA
Mapping of Aircraft Usage to Parts Tracking System
Life Credit QA
Maintenance Credits

DATA Q/A ASSESSMENT POINTS

Parameter Data Output

Load Factor (NZ)	Roll Angle	Rate of climb
1.0	0	0
1.1 0	10	0
1.15	20	0
1.18	25	100
1.18	30	200
2.00	60	400
2.00	60	600

Regime Output

Level flight

Climb

Turn 30 AOB

Level flight

Dive

Level flight

approach

hover

Component Damage Output

Component	**Damage**
Pitch Link	.00001
Rotor Hub	.00002
Swashplate	.00025
M.R. Blade	.00001

Q/A Assessment Approach

- Can the degradation be identified at points of assessment?

<u>Point of Detection</u> — <u>Means of Detection</u>

1. Parameter data output
   - Scan for missing parameter values
   - Check parameter magnitude drift against fleet wide bounds
2. Regime output
   - Evaluate for deviation in usage pattern for individual aircraft and fleet norm
   - Evaluate occurrences/ % time for increase or decrease against individual aircraft history and fleet norm
   - Screen individual maneuver durations for significant deviation
3. Damage rate output
   - Evaluate variance in individual component and fleet wide damage rates

BASIC MONITORING PARAMETERS

PARAMETER
Airspeed
Pitch Attitude
Roll Attitude
Pitch Rate
Roll Rate
Yaw Rate
Vertical Acceleration
Vertical Velocity
Engine Torque
Weight on Wheels
Rotor Speed
Fuel Quantity
Pilot Stick Positions
Altitude
Outside Air Temperature
Gross Weight
Rotor Brake

	V-22	H-53	H-60	AH-1Z	UH-1Y
Blade Fold	X	X	X	X	X
Sling Load	X	X			
Aerial Refuel	X				
Wing Stow	X				
Landing Gear Position	X				
Nacelle Angle	X				
Pylon Fold		X			
RAST			X		
Weapons Configuration				X	

TYPES OF PARAMETER DEGRADATION TO BE CONSIDERED

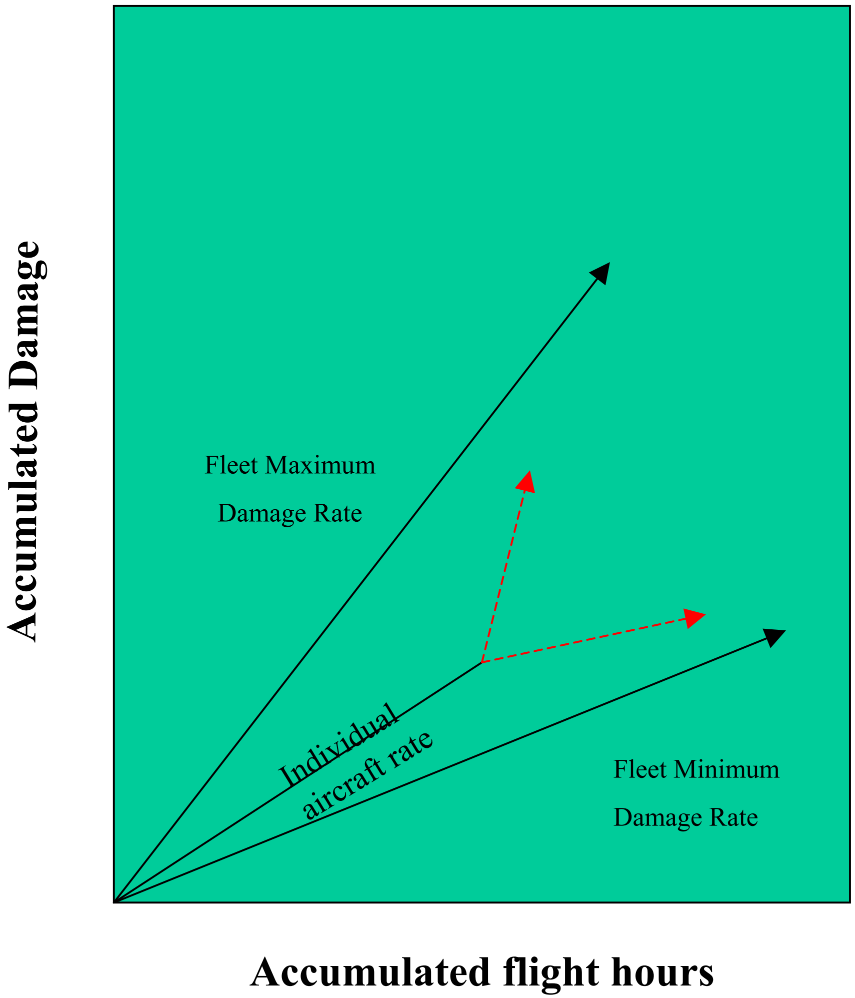
Parameter signal discrepancies

- Loss of Signal
- Random Loss of signal
- Bias signal --- high / low
  - Various magnitudes of degradation – 10%, 20%, etc.
- Drifting signal over time
- Band edge output

Data input discrepancies

- Erroneous estimates – high / low
- no data entered / submitted

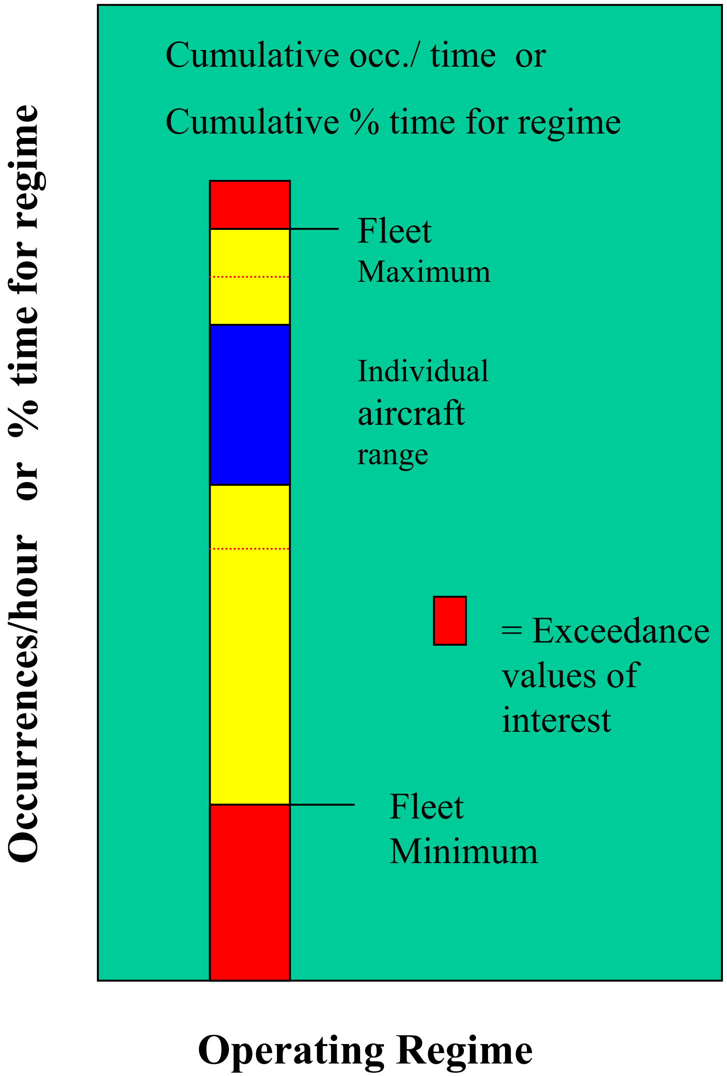
Detection Methods for Degraded Component Damage Rate Calculations

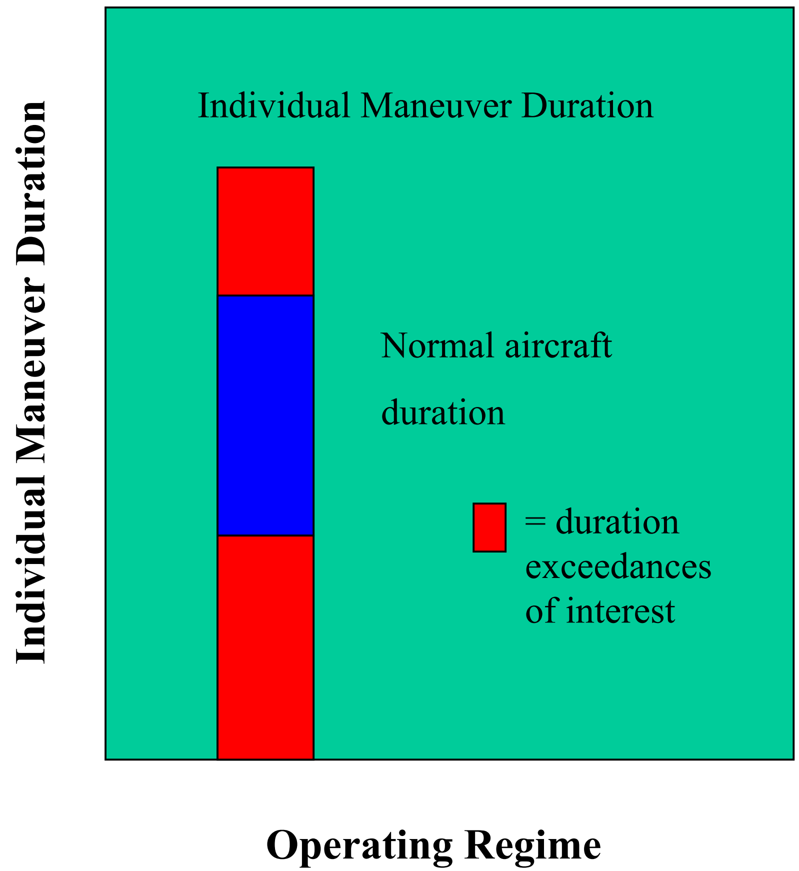


Evaluate component damage rate against:

- Previous individual aircraft component damage rate
- Fleet maximum and minimum damage rates for the component

Detection Methods For Degraded Regime Output





Baseline Usage Database Development

- Construct the “fleet baseline usage” data file
  - Use applicable flight test data from HUMS verification flights or original aircraft structural qualification flights
  - Use combinations of this data to construct a usage file that represents approx 3000 hours of fleet usage
- Use “fleet baseline usage” file to generate baseline statistics
  - Typical individual maneuver durations
  - Occurrence rate for certain maneuvers (turns, pullups, etc)
  - % Spectrum time for each applicable maneuver/regime

Degraded Condition Database Development

- Degraded flight data runs
  - Simulate various degraded data conditions
  - Many separate runs to evaluate the effect of various types of degradation
  - Degraded output will be compared to the baseline file
    - regime sequence
    - maneuver duration
    - # of occurrences of each regime
    - damage rates for select components
- Assess level of detect ability for each degradation type

Q/A Study Anticipated Results

1. Determine the feasibility of detecting various types of HUMS system degradation at the three possible data assessment points.
2. Identify the most effective method to use in detecting various types of system degradation.
3. Determine the limits of degradation detection possible for various types of HUMS systems
4. Provide some initial guidelines for Q/A criteria to detect system degradation

Q/A Study Sample Results

- SH-60B 1553 Databus Parameter Availability
  - 1553 is not mission essential
  - If a crewman rides in the back, the bus is powered up but crewman is not required to ride in the back
  - Result – 1553 databus signals not recorded for many flights
  - Airspeed is one of the parameters on this bus

Q/A Study Sample Results
Loss of Airspeed Measurement

- Degraded system data file was created to simulate loss of airspeed measurement, value set to zero
- Degraded system data results
  - High speed transient maneuvers no longer recognized
  - Level flight time above 50 knots changes dramatically
  - Low speed level flight time increases dramatically
- Conclusion
  - Loss of airspeed can be detected as a significant change in typical time spent in level flight
  - Loss of airspeed measurement can also be detected by inspection of regime input parameter data

Q/A Study Sample Results
Gain or Sensor Bias Problems

- A degraded system file was created where airspeed was increased by 10%
- Degraded system data results
  - No significant change in maneuvers recognized but a shift toward higher airspeeds occurs
  - Level flight, turns and pullups each have the same total time but higher percentage at high speed.
- Conclusion
  - This type of problem will be difficult to detect as a regime recognition anomoly
  - However, shift toward higher airspeeds will affect damage accumulation rate. Need to assess how much bias error will result in detectable anomolies.

Q/A Study Sample Results
Gain or Sensor Bias Problems

- A degraded system file was created where Nz was increased by 10%
- Degraded system data results
  - No significant change in maneuvers recognized but turns and pullups showed shift toward higher g-levels
  - Turns and pullups each have the same total time but higher percentage at high g-levels.
- Conclusion
  - This type of problem will be difficult to detect as a regime recognition anomoly
  - However, shift toward higher g-levels will affect damage accumulation rate. Need to assess how much bias error will result in detectable anomolies.

Q/A Study Sample Results
System Installation Errors

- Installation errors can lead to faulty signal measurements
  - Wires crossed on Nz for CH-53 initial prototype installation
- Prototype installation data review
  - Recorded data and regimes recognized compared to pilot card flight test maneuver descriptions
  - Example 1, Pilot card reports Symmetric Pullup flown
    - Recorded data: Nz dropped below one
    - Regime recognized: Pushover
  - Example 2, Pilot card reports Pushover flown
    - Recorded data: Nz goes above 1.0
    - Regime recognized: Pullup
  - Following identification of problem, reversed wire corrected

Q/A Study Sample Results
System Installation Errors

- A degraded system file was created simulating Nz having crossed wires
- Degraded system data results
  - More time spent in pushovers and less time spent in pullups
  - However, total time in pullups and pushovers is typically small
- Conclusion
  - Without a scripted pilot record of intentionally flown pullups and pushovers, this anomoly will be difficult to detect through a change in regime usage
  - Review of raw data would readily reveal this problem though
    - During turning flight, roll attitude will increase; as roll attitude increases, vertical acceleration will increase above 1g
    - A decrease in Nz below 1g during steady turning flight is an indication of a crossed Nz wire.

Summary and Planned Work

- Several data system anomolies have been investigated including a loss of parameter signal, sensor bias or gain errors, and a crossed wire signal.
- Preliminary results have shown that data integrity checks need to be in place at various levels in the structural monitoring process including:
  - Raw parameters
  - Regimes/usage spectrum recognized
  - Damage accumulation rate
- More rigorous and complete analysis is needed to provide detailed data integrity checks for each type of anomaly for each parameter of interest
- Parts tracking system data flow issues need to be investigated